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PUBLIC HEALTH REPORTS.

UNITED STATES.

[Reports to the Surgeon-General, Public Health and Marine-Hospital Service.]

SIPHONAPTERA OBSERVED IN THE PLAGUE CAMPAIGN IN CALIFORNIA, WITH A NOTE UPON HOST TRANSFERENCE.

By GEORGE W. MCCOY, Passed Assistant Surgeon, and MAURICE B. MITZMAIN, Technical Assistant, United States Public Health and Marine-Hospital Service, Plague Laboratory, San Francisco, Cal.

In the campaign against rodents for the purpose of exterminating the infection of plague among these animals in this vicinity, a systematic investigation has been made of the fleas found on the various animals that have come under observation. The results of the earlier studies at the Federal Plague Laboratory have been reported by Doane (1), Wherry (2), Fox (3), Mitzmain (4), and in the annual report of the Surgeon-General of the Public Health and Marine-Hospital Service (5). The present report is based upon observations made in the 6 months ended April 30, 1909.

The well-known fact that plague may be conveyed from rodent to rodent by means of fleas and the probability that the same agent serves to convey the disease from rodent to man make the study of the prevalence of these insects and of their host affiliations of great importance. As will be seen from the following tables, the large majority of fleas are found associated with their proper hosts, but there is, as other observers have previously noted, some accidental distribution to adventitious hosts. For example, the rat fleas have been found several times upon squirrels and the squirrel fleas upon rats. As both rats and squirrels showing plague infection have been found in California, the significance of this fact is at once apparent if we assume, as we are probably justified in doing, that plague may be carried from one of these rodents to the other by means of fleas. We have shown elsewhere (6) that all of the common rat fleas and squirrel fleas of this vicinity readily feed upon man's blood and that there is no reason why any flea from a rodent may not be the means of conveying plague infection, as has been demonstrated by the Indian Plague Commission (7) to be possible in the case of *Ceratophyllus fasciatus* Bosc. and *Loemopsylla cheopis* Roth.

Fleas have been combed from rats (some alive and some dead) by the employees of the sanitary service and sent to the laboratory for identification. The results are as follows:

FROM BROWN RATS (*Mus norvegicus*).

Number of rats combed.	<i>C. fasciatus</i> .		<i>L. cheopis</i> .		<i>P. irritans</i> .		<i>C. musculi</i> .		<i>C. canis</i> .	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
606	570	1,252	790	1,146	225	425	44	137	13	15

The average number of fleas per rat was 7.6. The largest number from any one rat was 77, all *L. cheopis*, 40 males and 37 females. We have no reliable data as to the number of rats that failed to yield fleas.

FROM BLACK RATS (*Mus rattus*).

Number of rats combed.	<i>C. fasciatus</i> .		<i>L. cheopis</i> .		<i>P. irritans</i> .		<i>C. musculi</i> .		<i>C. canis</i> .	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
11	7	32	6	5	0	0	4	17	0	2

Average per rat, 7.3, the largest number from any one rat being 14. In addition, from an unknown number of *M. rattus* we have taken:

<i>C. fasciatus</i> .		<i>L. cheopis</i> .		<i>P. irritans</i> .		<i>C. musculi</i> .		<i>C. canis</i> .	
Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
10	25	2	5	0	0	15	12	0	0

We have combed 114 *M. norvegicus* during the course of experiments to determine the regional distribution of fleas on rats. These rats were combed while under the influence of an anæsthetic or immediately after death.

Number of rats combed.	<i>C. fasciatus</i> .		<i>L. cheopis</i> .		<i>P. irritans</i> .		<i>C. musculi</i> .		<i>C. canis</i> .	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
114	46	139	59	89	.....	.....	29	104	.....	.....

A total of 466 fleas; an average of 4.7 per rat.

We have found squirrel fleas on rats upon 4 occasions: 2 males, *Ceratophyllus acutus*; 3 females, *Ceratophyllus acutus*; 1 female, *Hoplopsyllus anomalus*; and 1 male, *Ceratophyllus acutus*. These squirrel fleas were taken from rats caught in the outlying parts of the city. We have found squirrel fleas upon rats that have been kept in cages in proximity to our stock squirrel cages. In addition to these, Passed Asst. Surg. A. M. Stimson reports (personal communication) having found *Argopsylla gallinacea* on *Mus norvegicus* at Los Angeles, Cal., and we found *Ceratophyllus niger* on a *Mus norvegicus* on one occasion.

FROM RAT NESTS.

In the course of routine inspection of dwellings and stables in the carrying out of measures for plague suppression, a large number of rat nests were collected by the men employed in this work. Some of these nests were sent to the plague laboratory, where they were examined. It was found that many of them had been treated previously with a disinfecting fluid, thus destroying any life contained therein. These, for our purpose, were of no value. Two of the nests, however, had escaped the treatment, and we found 5 live young rats in one and 7 in the other. The nests, which were composed of straw and other material, were fairly well supplied with larvæ and adult fleas. Some of the young rats also harbored fleas. In one nest, 25 fleas, 10 male and 15 female, *C. fasciatus*, were found; and from the other we collected 39 specimens of the same species, 14 male and 25 female. The nest, as other writers have observed, appears to be the center of flea infestation. During the early days of this plague campaign, when plague rats were most abundant, medical officers engaged in sanitary work were impressed with the large number of rat fleas found in the nests of these rodents. Acting Asst. Surg. George M. Converse tells us that he has seen in stables rat nests which were so alive with fleas as to impart their color to the entire nest.

FROM MICE (*Mus musculus*).

From an unknown number of *Mus musculus* we have taken:

<i>C. fasciatus</i> .		<i>L. cheopis</i> .		<i>P. irritans</i> .		<i>C. musculi</i> .		<i>C. canis</i> .	
Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
1	5	2	0	0	0	3	10	0	0

FROM CALIFORNIA GROUND SQUIRRELS (*Citellus beecheyi*).

We have combed a large number of dead ground squirrels, from which we have obtained the following fleas:

Number of squirrels combed.	<i>Cerat acutus</i> .		<i>Hop. anomalous</i> .		<i>P. irritans</i> .	
	Male.	Female.	Male.	Female.	Male.	Female.
167	504	588	24	33	.....	2

A total of 1,151 fleas, an average of 6.8 per squirrel.

Live squirrels have been combed while under the influence of ether. From these we have obtained:

Number of squirrels combed.	<i>C. acutus</i> .		<i>Hop. anomalous</i> .	
	Male.	Female.	Male.	Female.
132	2,065	2,306	86	140

A total of 4,597 fleas, with an average of 34 from each squirrel. The largest number from any one squirrel was 376, all of which were *C. acutus*, 213 males and 163 females. We would call attention to the fact that the average number of fleas from a squirrel is much larger than the average number from the rat or any other host which we have observed. In addition to these squirrel fleas we have taken from the live squirrels mentioned:

<i>C. fasciatus.</i>		<i>L. cheopis.</i>		<i>P. irritans.</i>		<i>Ct. musculi.</i>		<i>Ct. canis.</i>		<i>Odontopsyllus wymani.^a</i>	
Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
4	9	2	6	0	1	1	3	2	0	1	0

^a This species is to be described by Passed Asst. Surg. C. Fox in an early number of the Entomological News.

These were from squirrels as they were brought to the laboratory, but the possibility of some of these fleas, which properly belong to other hosts, having got upon the squirrels in the laboratory can not be entirely excluded.

FROM RABBITS (*Lepus auduboni*).

(From San Francisco, Berkeley, and Los Angeles.)

Number combed.	<i>P. irritans.</i>		<i>Spilopsyllus inaequalis.</i>		<i>Hop. affinis.</i>		<i>Hop. anomalus.</i>		<i>C. dentatus.</i>	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
6	0	1	8	21	.....	9	2	4	1	0

A total of 45 fleas from 6 rabbits.

FROM THE WEASEL (*Putorius zanthogenys*).

Number combed.	<i>C. fasciatus.</i>		<i>C. ignotus.</i>		<i>C. Wagneri.</i>		<i>C. acutus.</i>		<i>Hop. anomalus.</i>		<i>C. telchinum.</i>	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
5	0	2	1	0	3	5	2	1	0	2	0	1

This large assortment of fleas, comprising representatives of species proper to rats, gophers, squirrels, rabbits, and field mice, in addition to the weasel flea, *C. wagneri*, is what would be expected when the predatory habits of this marauding rodent are considered.

FROM THE SKUNK (*Mephitis occidentalis*).

Number combed.	<i>P. irritans.</i>		<i>C. acutus.</i>	
	Male.	Female.	Male.	Female.
3	9	8	0	2

Passed Asst. Surg. Carroll Fox (8) has called attention to the fact that *P. irritans* is a constant parasite of the skunk in the vicinity of San Francisco. The skunk from which the *C. acutus* was taken was caught in a squirrel burrow.

FROM THE MOLE (*Scapanus californicus*).

Number combed.	<i>Corypsylla ornatus.</i>	
	Male.	Female.
1	2	2

FROM THE RACCOON (*Procyon psora*).

Number combed.	<i>Spilopsyllus inæqualis.</i>		<i>C. wagneri.</i>	
	Male.	Female.	Male.	Female.
1	2	2	1	0

FROM THE GOPHER (*Thomomys bottæ*).

Number combed.	<i>C. ignotus.</i>		<i>C. acutus.</i>		Total.
	Male.	Female.	Male.	Female.	
12	22	40	5	8	75

FROM THE FIELD MOUSE (*Microtus californicus*).

Number combed.	<i>C. telchinum.</i>	
	Male.	Female.
1	2	2

FROM THE BOOBY OWL (*Speotyto cunicularia hypogæa*).

Number combed.	<i>C. acutus.</i>		<i>H. anomalus.</i>	
	Male.	Female.	Male.	Female.
1	1	.....	.....	1

This owl was trapped in a ground-squirrel burrow.

FROM THE DOG (*Canis familiaris*).

Number combed.	<i>Ct. canis.</i>		<i>P. irritans.</i>		<i>Ct. felis.</i>		<i>C. acutus.</i>	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
4	10	44	8	17	0	1	1	0

The *Ct. felis* was taken from a dog that yielded in addition a number of specimens of *Ct. canis*. We agree with Rothschild (9) that *Ct. felis* is quite distinct from *Ct. canis*. We have, however, found both species on the dog.

FROM THE CAT (*Felis domestica*).

Number combed.	<i>Ctenocephalus felis</i> .	
	Male.	Female.
2	5	15

FROM MAN (*Homo sapiens*).

Number of individuals.	<i>P. irritans</i> .		<i>Ct. felis</i> .		<i>Ct. canis</i> .		<i>C. acutus</i> .	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
29	117	220	1	0	1	0	1	2

The squirrel fleas (*C. acutus*) have been taken on members of the laboratory staff who, in the course of their duties, have been brought into rather close association with squirrels. In each case the flea was taken while actually in the act of biting. We have shown elsewhere (6) that squirrel fleas readily bite man under experimental conditions.

TRANSCIENCE TO NEW HOST.

We have called attention above to the fact that plague exists among the ground squirrels of California. There is good reason for suspecting that this infection among the ground squirrels originated from plague among rats, and as it has been demonstrated that rat plague is propagated most frequently through the medium of fleas, the suspicion naturally arises that the infection among the squirrels may have been derived from the rat through the medium of the flea. We deemed it desirable therefore to attempt to determine in an experimental way whether fleas from one of these rodents would attack the other rodent and whether the 2 rodents would live together in captivity.

The presence of squirrel fleas on rats in nature has been recorded by Doane (1) and by Fox (8), and as stated above we have observed the same thing in a number of instances, and have, on several occasions, found rat fleas on squirrels taken in nature.

These experiments were conducted in 2 ways. First, fleas were taken from one of the hosts and placed in a mouse jar, or in an animal cage with the other host, and after a varying period of time, the new host was chloroformed and the fleas were carefully collected, identified, and enumerated. It is obvious that this method hardly simulates the conditions in nature. The second procedure was to liberate a rat in a cage with a number of squirrels, or, which accomplished the same purpose, to confine the rat in a cage trap which was placed in a large box cage containing squirrels. This method somewhat more closely simulates the condition under which the animals might be associated in nature.

We might here call attention to the fact that when rats and squirrels are placed in the same cage they live together in perfect harmony. We have never had either a black or a brown rat killed when placed in a cage with squirrels.

TRANSFERENCE FROM RATS TO SQUIRRELS.

Original host.	Fleas, species and number.	Length of time on new host.	Fleas recovered, species and sex.
<i>M. norvegicus</i>	<i>L. cheopis</i> , 30 specimens.	<i>C. beecheyi</i> , 6 days.....	<i>L. cheopis</i> , 1 female.
Do.....	<i>C. fasciatus</i> , 25 specimens	<i>C. beecheyi</i> , 7 days.....	<i>C. fasciatus</i> , 1 male and 10 females.
Do.....	<i>L. cheopis</i> , 135 specimens.	<i>C. beecheyi</i> , 3 days.....	<i>L. cheopis</i> , 2 males and 7 females.

TRANSFERENCE FROM SQUIRRELS TO RATS.

Original host.	Fleas, species and number.	Length of time on new host.	Fleas recovered, species and sex.
<i>C. beecheyi</i>	<i>C. acutus</i> , 44 specimens..	<i>M. norvegicus</i> , 10 hours..	<i>C. acutus</i> , 1 male and 2 females.
Do.....	<i>C. acutus</i> , 42 specimens; <i>H. anomalus</i> , 9 specimens.	<i>M. norvegicus</i> , 3 days....	<i>C. acutus</i> , 4 males and 1 female; <i>H. anomalus</i> , 2 males.

RATS PLACED IN CAGE WITH SQUIRRELS.

Original host.	New host.	Time of exposure.	Fleas recovered from new host.
<i>C. beecheyi</i>	<i>M. rattus</i>	14 days....	<i>C. acutus</i> , 1 male and 1 female.
Do.....	<i>M. norvegicus</i> (2).....	1 day.....	<i>C. acutus</i> , 2 males and 6 females.
Do.....	<i>M. norvegicus</i> (2).....	10 days....	<i>C. acutus</i> , 22 males and 10 females.
Do.....	<i>M. norvegicus</i>	17 hours....	<i>C. acutus</i> , 1 female.
Do.....	<i>M. norvegicus</i>	4 hours....	<i>C. acutus</i> , 1 male and 1 female.
Do.....	<i>M. norvegicus</i> (2).....	5 hours....	<i>C. acutus</i> , 4 females.
Do.....	<i>M. norvegicus</i> (6).....	2 days....	<i>C. acutus</i> , 9 males and 7 females.
Do.....	<i>M. norvegicus</i> (4).....	4 days....	<i>C. acutus</i> , 10 males and 15 females.
Do.....	<i>M. norvegicus</i> (3).....	1 week....	<i>C. acutus</i> , 87 males and 114 females.

These experiments indicate that fleas from rodents will adapt themselves to a host of a different species. They also demonstrate that fleas from squirrels will attack rats even in the presence of the normal host.

LIST OF SPECIES MENTIONED IN THIS PAPER.

Argopsylla gallinacea (Westwood) Enderlein.
Ceratophyllus acutus Baker.
Ceratophyllus dentatus Baker.
Ceratophyllus fasciatus Bosc.
Ceratophyllus ignotus Baker.
Ceratophyllus niger Fox.
Ceratophyllus telchinum Roth.
Ceratophyllus wagneri Baker.
Corypsylla ornatus Fox.
Ctenocephalus canis (Curtis) Baker.
Ctenocephalus felis Bouche.
Ctenopsyllus musculi (Duges) Wagner.
Hoplopsyllus affinis Baker.
Hoplopsyllus anomalus Baker.
Loemopsylla cheopis Roth.

Odontopsyllus wymani Fox. (To appear shortly in Entomological News.)

Pulex irritans Linn.

Spilopsyllus inæqualis Baker.

Total number of fleas identified, 12,347.

REFERENCES.

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- (4c) Ibid., pp. 353-359. Insect Transmission of Bubonic Plague; A Study of the San Francisco Epidemic.
- (4d) 1909. Canadian Entomologist, May, 1909. List of the Siphonaptera of California.
- (5) 1908. Annual Report, Surgeon-General U. S. Public Health and Marine-Hospital Service.
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- (7) 1906. Journal of Hygiene, Extra Plague Number, Vol. VI, No. 4. Ibid., 1907, Vol. VII, No. 3; Ibid., No. 6; Ibid., 1908, Vol. VIII, No. 2.
- (8) 1909. Fox, Entomological News, Jan., 1909, p. 10. A Report on the Species of the Siphonaptera Found Within the Boundaries of the City and County of San Francisco.
- (9) 1901. Rothschild, Entomologist's Record, Vol. XIII, No. 4, p. 126. Notes on *Pulex canis*, Curtis, and *Pulex felis*, Bouche.

Reports from San Francisco, Cal.—Plague-prevention work at San Francisco, Oakland, and Point Richmond, and in Alameda and Contra Costa counties, Cal.—Plague squirrels found in Contra Costa County.

Surgeon Blue reports:

SAN FRANCISCO, CAL.

Date of last case of human plague: Sickened, January 30, 1908.

Date of last case of rodent plague: October 23, 1908.

Week ended June 5, 1909.

Sick inspected.....	4
Plague.....	0
Dead inspected.....	106
Plague.....	0
Necropsies held.....	1
Premises inspected.....	1,779
Houses disinfected.....	72
Buildings condemned.....	11
Nuisances abated.....	243
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Rats found dead.....	51
Rats trapped.....	2,441
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Total rats taken.....	2,492
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